UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Office of Air Quality Planning and Standards (OAQPS)
Research Triangle Park, North Carolina 27711

MEMORANDUM

SUBJECT: A Distributional Comparison between Different Rollback Methodologies Applied to Ambient Ozone Concentrations

FROM: Michael Rizzo, EPA-OAQPS, Air Quality Analysis Group

TO: Ozone NAAQS Review Docket (OAR-2005-0172)

DATE: August 23, 2006

This memorandum supersedes the memorandum submitted to the Ozone NAAQS Review Docket dated May 31, 2006 to correct an error in the figures provided in the appendix.

For the prior ozone NAAQS review, one of the methods, referred to as the "Quadratic Method," developed for adjusting ozone ambient air concentrations to simulate just meeting alternative standards combined both linear and quadratic elements to reduce larger concentrations more than smaller ones.[1] In this regard, the Quadratic method attempts to account for reductions in emissions without greatly affecting lower concentrations near ambient background levels. Other rollback algorithms have either fit the data to a particular distribution such as the Weibull method or used a linear, proportional rollback where all of the ambient measurements are reduced by the same percentage regardless of their individual magnitudes.[2]

This memorandum will compare two of the above mentioned rollback methodologies: quadratic and percentile proportional. As the name implies, the quadratic method uses a quadratic equation to reduce higher ozone concentrations more than smaller ones. The amount of rollback depends on the magnitude of the reduction of the existing fourth maximum to meet the standard. Sites which have data with high ozone concentrations are subjected to a more substantial rollback than those which are at or below the National Ambient Air Quality Standards. In contrast, the percentile proportional rollback uses a dual linear approach where ozone concentrations less than a specified percentile are not

1 Duff, Marcus; Horst, Robert L.; Johnson, Ted R.; "Quadratic Rollback: A Technique to Model Ambient Concentrations Due to Undefined Emission Controls". Paper No. 98-TA32.07 Air and Waste Management Annual Meeting. San Diego, California. June 14-18, 1998.

2 Johnson, Ted; A Guide to Selected Algorithms, Distributions, and Databases Used in Exposure Models Developed by the Office of Air Quality Planning and Standards. EPA Grant No. CR827033. May 2002. http://www.epa.gov/ttn/fera/data/human/report052202.pdf

rolled back while those greater than the percentile value are proportionally rolled back based upon the difference between the measured fourth maximum and the calculated value needed to attain the standard.

Method Descriptions

Quadratic Rollback

The Quadratic Rollback method takes the form of the following equation

$$C'_j = r_j C_j$$

where : C'_j is the rolled back concentration
r_j is the quadratic rollback factor unique to each measurement
C_j is the original measured concentration

The quadratic rollback factor is defined as

$$r_j = V - BC_j$$

where: V and B are positive constants determined from an individual site's measurements.

This method has both linear and quadratic terms so that greater ozone concentrations are subject to a greater reduction than lower ones. This technique attempts to mimic possible control strategy reductions in ozone concentrations where ozone exposure is abated by shaving the peak ozone values in an overall distribution but having little or no effect on very low concentrations. However, because the method is curvilinear, mid range values could slightly increase in order to allow for larger decreases in higher ozone concentrations while still maintaining little or no change in low concentrations. More details on the quadratic rollback method can be found in the two previously cited references.[1,2]

Percentile Proportional Rollback

The percentile proportional rollback technique was the linear approach chosen for comparison to the quadratic rollback. For the percentile proportional rollback, the relationship between the adjusted and actual hourly ozone concentrations changes at a specified value represented by a percentile of the hourly data's distribution. The first of the two relationships follows a line with slope equal to one between the adjusted and actual ozone concentrations up to the percentile value chosen. This can be represented as:

$$C_{adj} = C_{act} \text{ when } C_{act} <= C_{pctl}$$

where: C_{adj} is the adjusted hourly ozone concentration
C_{act} is the actual hourly ozone concentration
C_{pctl} is the value of the chosen percentile (e.g. 50^{th}, 60^{th}, 70^{th}, 80^{th} and 90^{th}) of the hourly ozone data distribution

The second relationship is a line which passes through the points at the chosen percentile value and the values of the adjusted and actual air quality indicator for the design value site. This allows for a continuous relationship across the range of hourly ozone concentrations with two segments representing the values below and above the chosen percentile. This relationship can be expressed as:

$$C_{adj} = \beta_0 + \beta_1 * C_{act} \text{ when } C_{act} > C_{pctl}$$

where: C_{adj} is the adjusted hourly ozone concentration

C_{act} is the actual hourly ozone concentration
β_0 is the intercept of the line

β_1 is the slope of the line

C_{pctl} is the value of the chosen percentile (e.g. 50^{th}, 60^{th}, 70^{th}, 80^{th} and 90^{th}) of the hourly ozone data distribution

The slope (β_1) and intercept (β_0) of the line are calculated from the two points which the line passes through.

$$\beta_1 = (S-C_{pctl})/(AQI-C_{pctl})$$

$$\beta_0 = C_{pctl} - (\beta_1 * C_{pctl})$$

where: AQI is the air quality indicator which in this case is the 8 hour 4^{th} maximum value

S is the concentration which the high year 8 hour 4^{th} maximum concentration is rolled back to

The percentile proportional rollback was calculated using the 50^{th}, 60^{th}, 70^{th}, 80^{th} and 90^{th} percentiles from the hourly ozone concentrations from the sites listed in Table I. Rolled back values were truncated after the third decimal place to be consistent with the current ozone reporting methodology as well as the procedures for calculating 8 hour ozone concentrations.

Data

Data from eight sites within three major urban areas were used to calculate rolled back ozone concentrations using the quadratic method. For each site, a high and low ozone year was chosen based on historical data. The information detailing the high and low years and the corresponding eight hour averaged 4th maxima are provided in Table I.

Table I: List of Sites and Respective High/Low Ozone Years Utilized

Site ID	High ozone		Low ozone		City/Urban Area
	Year	8 hour 4th max	Year	8 hour 4th max	
060371601	1994	127	2002	74	Los Angeles
060372005	1994	132	2001	90	Los Angeles
060658001	1994	148	2000	106	Los Angeles
060711004	1994	148	2002	105	Los Angeles
171630010	1995	84	2001	78	St. Louis
291831002	1995	112	2001	85	St. Louis
420170012	1995	111	2003	87	Philadelphia
420450002	1995	108	2003	80	Philadelphia

The ozone concentrations measured in the high year were rolled back to the low year concentrations based on the differences in the 4th maxima.

The value to roll the fourth maximum 8 hour ozone values back to for each monitor-year is denoted as S. The value of S for each monitor-year is determined by the amount of rollback required to have the average fourth maximum ozone concentration over three years attain the standard. To accomplish this, the design value for each site is multiplied by a reduction factor calculated as:

$$\text{Reduction Factor} = C_{att}/C_{dv}*100$$

where: C_{att} is the attainment concentration for the ozone standard which is 0.084 ppm

C_{dv} is the average of the fourth maxima at the design value monitor for a particular area over a three year period

The value (S) which each fourth maximum in a three year is rolled back to is calculated as:

$$S_k = \text{Reduction Factor}*C_{max k}$$

where: S_k is the rollback or target value for year k

C_{maxk} is the fourth maximum for year k

For the purpose of this work, S reflects the low year 4th maximum concentration to which the high year's 4th maximum concentration needed to be rolled back.

Results

Figures 1 through 8 in the Appendix display the absolute values of the differences between the individual rollback methods' distributional statistics to those from the low ozone year's concentration distribution. As noted above, five percentiles ranging from the 50th to the 90th were used to calculate the proportional rollback. The differences between each rollback method to the original ozone concentrations for each of the distributional statistics do not vary much at sites which do not have a large range of ozone concentrations such as those near the St. Louis and Philadelphia areas. In areas where there are large differences in the minimum and maximum ozone concentrations such as Los Angeles there is a much larger difference in the methods when compared to the original low year ozone distribution. Since the proportional rollback uses a distributional cut point up to which the ozone data are not reduced, differences between the rolled back values and the low ozone year's concentrations from the distribution's minimum to the 10th or 25th percentile are near zero at most of the sites examined.

Comparing the differences between the rollback methods and the original distribution for the higher percentiles usually shows that the quadratic rollback has a smaller difference than its proportional counterparts. The largest differences between the two methods occur for the maxima of each distribution with smaller differences being seen in the Philadelphia and St. Louis areas. In general, the proportional rollback appears to differ from the low ozone year data more at specific percentile cut points than does the quadratic which does not rely on any specified percentile to dictate the amount of rollback required. This makes the quadratic method easier to implement since it is not necessary to iterate through a series of percentiles to find the best distributional fit with the original data. Furthermore, the quadratic method does not exhibit the small spike in the number of rolled back ozone concentrations at certain intervals as the percentile proportional rollback does which is most likely due to the change in slope at a specified percentile.

The Ozone Air Quality Criteria Document stated that "high" ozone days can be represented by values at or above the 95th percentile.[3] The differences between the two methods and their iterations are similar to one another for this statistic. Since it appears that the two methods produce similar results with the quadratic method being somewhat better for "high" day concentrations, methodological consistency with the 1996 ozone staff paper which utilized the quadratic rollback may allow for better comparison of results with previous analyses.

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[3] U.S. Environmental Protection Agency (2006). Air Quality Criteria for Ozone and Related Photochemical Oxidants. Research Triangle Park, NC: Office of Research and Development; Report no. EPA 600/R-05/004bF.

APPENDIX

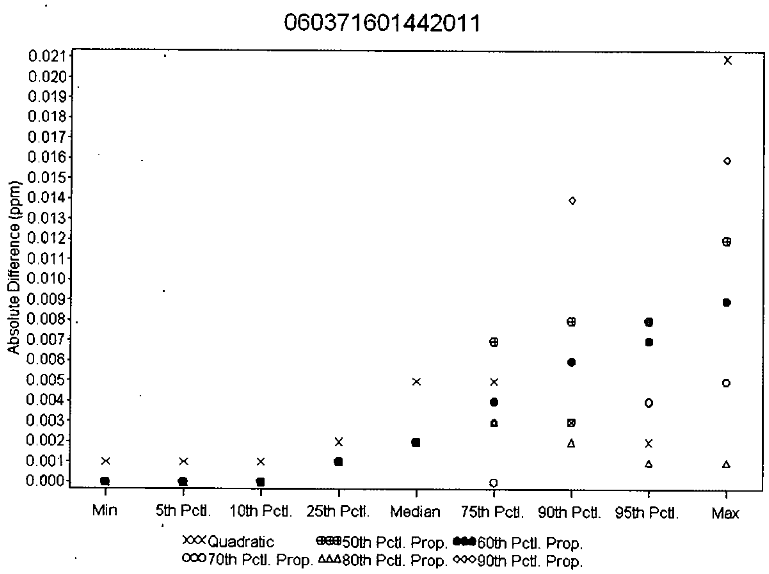


Figure 1. Rollback Distribution Comparisons for a Site in Pico Rivera, CA

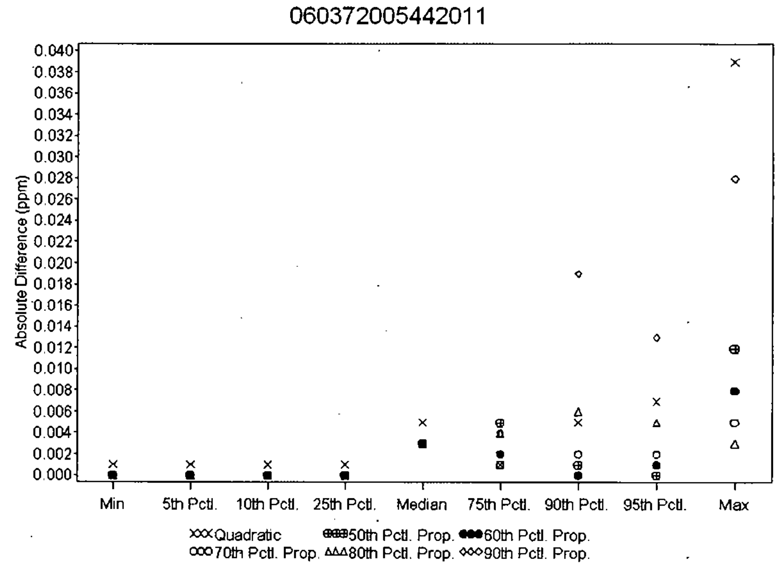


Figure 2. Rollback Distribution Comparisons for a Site in Pasadena, CA

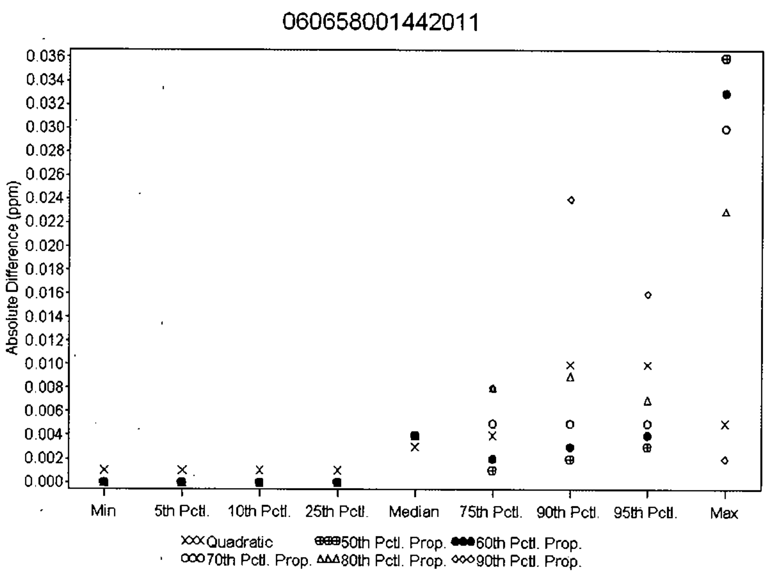


Figure 3. Rollback Distribution Comparisons for a Site in Rubidoux, CA

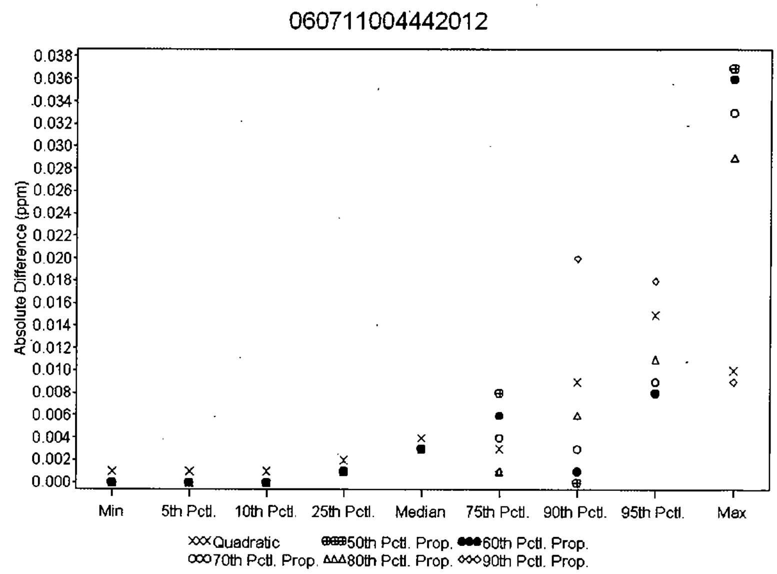
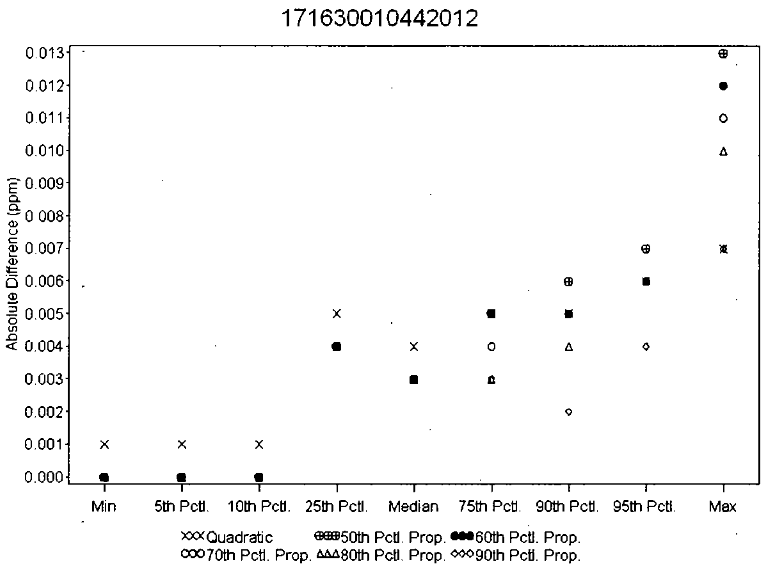


Figure 4. Rollback Distribution Comparisons for a Site in Upland, CA



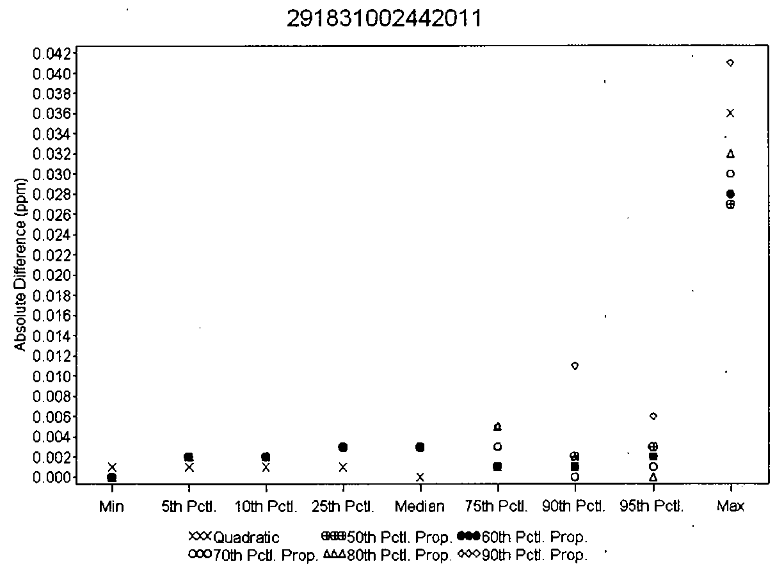
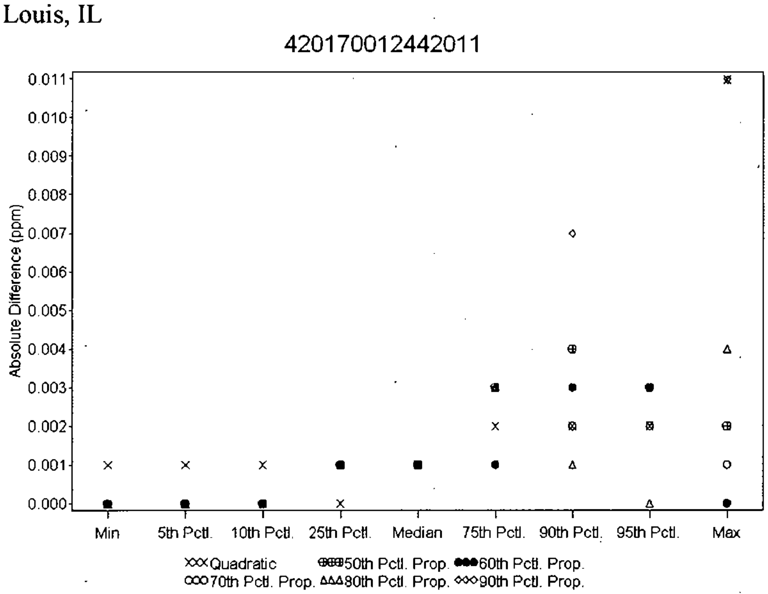


Figure 5. Rollback Distribution Comparisons for a Site in East St. Louis, IL

Figure 6. Rollback Distribution Comparisons for a Site near Alton, MC



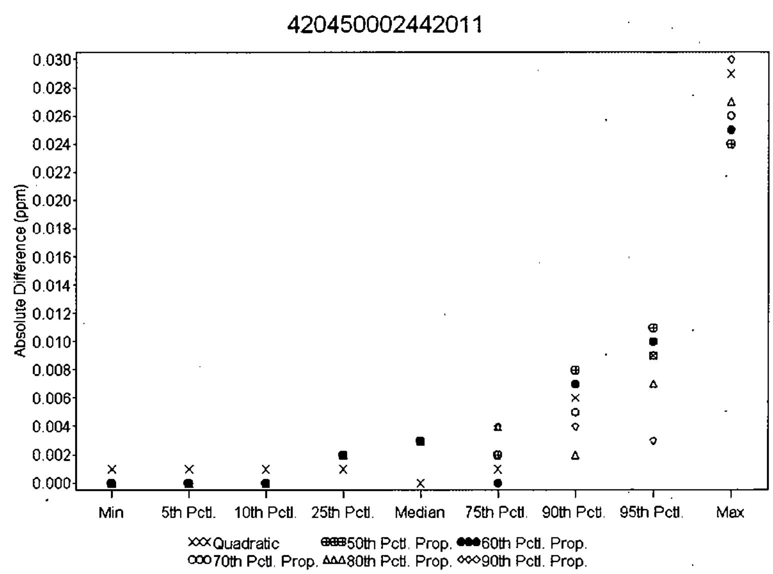


Figure 7. Rollback Distribution Comparisons for a Site in Bristol, PA

Figure 8. Rollback Distribution Comparisons for a Site in Chester, PA